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David J. Rickeard
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TITLE: METHOD FOR REDUCING EMISSIONS FROM HIGH PRESSURE COMMON RAIL FUEL INJECTION DIESEL ENGINES

CASE NO. JJA-0107

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APPLICATION FOR UNITED STATES PATENT

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CROSS REFERENCE TO RELATED APPLICATION:

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Case No. JJA-0107

METHOD FOR REDUCING EMISSIONS FROM HIGH PRESSURE COMMON RAIL FUEL INJECTION DIESEL ENGINES

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0001] This invention relates to the operation of compression ignition engines, i.e., diesel engines, utilizing high pressure common rail fuel systems and to the fuels used to run such engines.

DESCRIPTION OF THE RELATED ART

[0002] In the operation of compression ignition diesel engines fueled with conventional fuel systems, i.e., high pressure diesel injectors, the fuel used is a distillate fuel which is higher viscosity and density than most other transportation distillate fuels, e.g., gasoline, jet fuel, etc. A drawback of using such fuel in such conventional fuel system engines can be high smoke production.

[0003] It is generally known that low density fuels are environmentally desirable. These fuels are also often associated with their lower aromatic content, lower sulfur content, lower T_{90} and lower content of polynuclear aromatic compounds. Sulfur and aromatics are typically reduced by incorporating hydrogen into the fuel molecules (i.e., raising the H/C ratio). This can have the effect of reducing fuel density and volumetric energy content. In general, when sulfur and aromatics are reduced density goes down, the fuel burns cleaner and the exhaust is more effectively cleaned by exhaust after treatment systems like catalytic converters and particle traps. It is also generally acknowledged, however, that the use of low density diesel fuels in conventional fuel system

diesels reduces engine output and degrades vehicle performance. This is due to the lower volumetric energy content of low density fuels.

DESCRIPTION OF THE FIGURE

[0004] Figure 1 reports the emission levels of hydrocarbon, NO_X, particulate matter, hydrocarbon + NO_X and CO produced (means of three runs) by a common rail diesel engine run on four fuels of different density and viscosity.

DESCRIPTION OF THE INVENTION

[0005] It has been discovered that compression ignition engines utilizing high pressure common rail fuel systems can be operated with good performance and reduced emissions of hydrocarbons, particulate matter and CO by the use of low density fuel characterized as a fuel having density of about 0.83 g/cc or less, preferably about 0.825 g/cc or less, more preferably about 0.82 g/cc or less, a kinematic viscosity of about 3 cSt or less at 40°C, preferably about 2.6 cSt or less at 40°C, more preferably about 2.1 cSt or less at 40°C. Diesel fuel refers to an essentially hydrocarbon fuel which can contain various amounts of oxygen, sulfur, nitrogen and various trace elements, with a distillation curve falling in the range of about 140°C to 400°C.

[0006] Preferably the fuel also has a sulfur content of about 0.05 wt% or less, more preferably about 0.04 wt% or less, still more preferably about 0.03 wt% or less. Sulfur can be measured by x-ray fluorescence and ultraviolet fluorescence. One particularly effective method for measuring low levels of distillate fuel sulfurs is ASTM D-5453. The fuel may also contain such other typical diesel fuel additives as cetane improvers pour point depressants/cold flow improvers, oxygenates (such as alcohols, ethers, esters, glycols, etc.), wax anti-settling

additives, diesel fuel stabilizers, antioxidants, combustion improvers, detergents, demulsifiers, dehazers, lubricity additives, antifoamants, antistatic agents, conductivity improvers, corrosion inhibitors, drag reducing agents, reodorants, dyes, markers and the like.

[0007] While lower density fuels contain less energy per unit volume and consequently result in a loss of engine performance in conventional high pressure injector fuel system engines, it has been found, quite unexpectedly, that high pressure common rail fuel system compression ignition engines can be operated with no performance debit and with a significant reduction in emissions by using as the fuel a low density diesel fuel characterized as a fuel having a density of about 0.83 g/cc or less, a viscosity of about 3 cSt or less at 40°C and preferably a sulfur content of about 0.05 wt% or less.

[0008] The invention is further described in the following non-limiting examples.

[0009] Four test fuels are described in Table 1, below.

TABLE 1

	METHOD	UK LS ADO	SWISS LS ADO	R-IMPROVED ADO	SWEDISH CLASS 1 ADO
Density (g/cm^3)	IP 365	0.8539	0.8251	0.8212	0.8155
K.V. @ 40°C (cSt)	ASTM D4 45/6	3.475	2.078	2.637	2.008
Sulfur (% wt)	RD 86/10	0.05	0.03	0.05	< 0.01
Distillation (°C)	ASTM D86				
IBP		184	166	192	179
T10		241			
T50					
T90					
T95					
FBP					
Cetane Number	ASTM D613	50.1	49.9	56.6	56.4
Aromatics (% m/m)	IP 391				
Mono		20.3	21.4	13.9	4.1
Di		5.0	3.4	2.8	0.0
Tri +		1.4	0.5	0.2	0.0
Di + Tri		6.4	4.0	3.0	0.0
Total		26.7	25.4	16.9	4.1

4 test fuels (3 commercial European fuels + 1 experimental fuel)

- UK (high density / low volatility)
- Swiss (low density / high volatility)
- Swedish Class 1 "City" diesel
- "R-Improved" research fuel

[0010] Three fuels are commercially available European specification diesel fuel and one is a laboratory blended fuel. The fuels were tested in a Mercedes C220CDi vehicle, the first commercial European common rail diesel vehicle. Cold start emissions are tabulated in Figure 1.

[0011] It is seen that hydrocarbon emissions decrease as the engine is switched from UKLSADO (density 0.8539 g/cc) to Swiss LAADO (density 0.8251 g/cc) to R-Improve ADO (density 0.8212 g/cc) down to Swedish Class 1 "City" diesel (density 0.8155 g/cc).

[0012] A similar trend is seen with respect to particular matter (P_m x 10) and CO. There is no significant difference in NO_x production from the engine run on any of the four fuels.

[0013] The UK low sulfur ADO produced the highest emissions. Emissions of hydrocarbons, particulate matter and CO were all reduced by switching to lower density, lower viscosity fuels.

[0014] Vehicle performance was measured by doing wide open throttle acceleration in fifth gear. Acceleration time form 50 to 120 km/hour was measured. Despite the difference in the fuels with respect to densities, there was no significant difference in acceleration times as would be expected in a conventional diesel engine.

[0015] Acceleration times are presented in Table 2, below.

TABLE 2

UK LS ADO	26.61 seconds
Swiss LS ADO	26.75 seconds
R-Improved ADO	26.86 seconds
Swedish Class 1 ADO	26.85 seconds

[0016] Statistical analysis disclosed that there is no difference in acceleration performance between the fuels (based on the 95% LSD intervals). Analysis based on the 60% LSD intervals still did not show a difference between any of the fuels.

[0017] Consequently, it is seen that the operation of common rail diesel engines in diesel fuels of lower density and viscosity, while resulting in a significant reduction in emissions has no significant effect or overall vehicle performance, as determined by acceleration.